Acta orthop. scand. *50*, 205–216, 1979

TOTAL HIP REPLACEMENT WITH A TRUNNION BEARING PROSTHESIS

Biomechanical Principles and Preliminary Clinical Results

IAN F. GOLDIE & CHRISTINA RANER

Department of Orthopaedic Surgery II, Sahlgren Hospital, University of Göteborg, Göteborg, Sweden.

The biomechanics are presented of a bushing principle forming the basis for a trunnion bearing prosthesis in total hip replacement. The femoral stem is equipped with a trunnion on to which a cylindrical plastic sleeve is applied. On top of this a metal casing is placed which forms the femoral head. On flexion-extension this remains stationary in the acetabular cup and motion occurs between the trunnion and the cylindrical sleeve. Friction between head and cup is reduced to a minimum, decreasing the risk of loosening.

A follow-up study of 61 hips replaced by the trunnion bearing prosthesis was performed 2.5 years postoperatively. Eighty-eight per cent were considerably improved. There was one deep infection and two femoral stem loosenings.

Key words: bushing principle; diminished friction; less loosening; total hip replacement; trunnion bearing prosthesis

Accepted 12.ix.78

At present some 1000 total hip replacements are carried out daily in the Western world (Bloch 1976, personal communication). In Great Britain with 58 million inhabitants about 30,000 hips are replaced per year (Lancet 1976) and in Sweden with 8 million inhabitants there are about 3000 hip replacements annually (Herberts 1978, personal communication).

The results are good and Eftekhar & Stinchfield (1973), reporting a series of 700 operated hips, found that 70 per cent were still completely free of pain 4 years after the operation. Charnley (1970, 1975) reported freedom of pain in 96 per cent in a 5-year study and after 15 years there was a successful result in 79 out of 90 patients who were still alive (Charnley 1978).

In 1976 at the 26th North West German Orthopaedic Congress no less than 36 of the papers presented were about complications after total hip replacement and the most common were dislocation of the prosthesis, infection, loosening, fracture of the prosthesis, the cement or bone, allergic reactions and complications arising from the surrounding soft tissue. In all, 10–15 per cent of all total hip replacements are marred by complications (Lancet 1976).

Besides infection, loosening is a dreaded complication and the variety of designs of total hip prosthesis available reflects the

0001–6470/79/020205–12$02.50/0

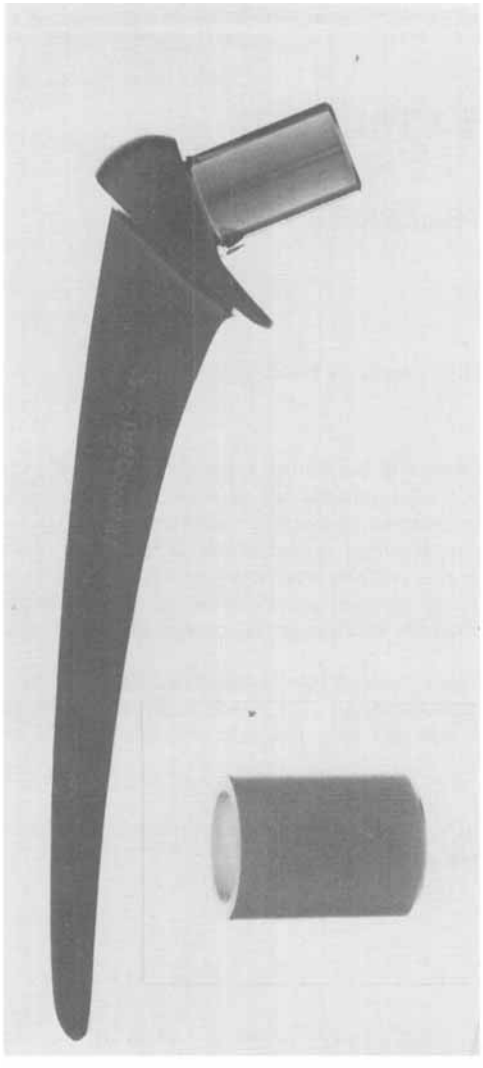

Figure 1 A. Christiansen's trunnion bearing prosthesis. Femoral component. Trunnion at proximal end forms an angle of 115° with axis of the stem. Inset: cylindrical sleeve to be passed on to the trunnion.

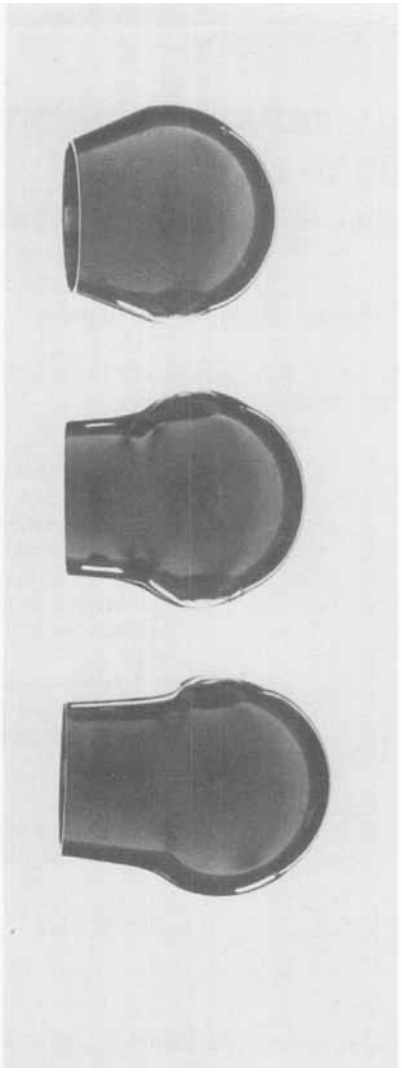

Figure 1 B. Spherical casings in metal to be placed on the trunnion. Varying neck lengths: top: 5 mm; middle: 10 mm; bottom: 15 mm.

desire to construct a prosthesis which will be least hampered by complications. In 1969 a new prosthetic system was introduced for total replacement of the diseased hip joint (Christiansen 1969). The system is based on a trunnion bearing principle with the object of diminishing friction between the articulating surfaces. Since its introduction more than 2500 patients operated in Scandinavian hospitals have been fitted with this prosthesis. Christiansen (1977, personal communication) has treated about 250 patients, the longest observation time being 7 years and the shortest 2 years. Using the Love/Charnley classification for evaluation of results, Christiansen found, in his material, 57

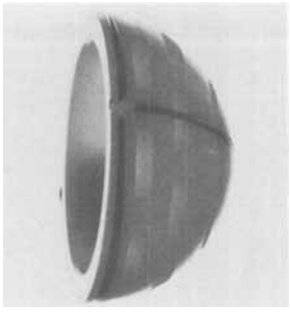

Figure 1 C. Acetabular cup made of Delrin. Internal diameter 37 mm. External diameters 47 and 51 mm.

per cent excellent and 33 per cent good results; in other words satisfactory results in 90 per cent. In all, there were 21 complications, i.e. almost 10 per cent. There was infection in six cases, loosening in seven, dislocation in two, perforation into the pelvis in two and heterotopic ossification in four.

So far, no further reports of this new device have been published and in this presentation a preliminary clinical follow-up study is reported and the biomechanical principles of the design are described and partly analysed. This forms the first of a series of reports which include an analysis of the movements of the various components of the prosthetic system, a strain gauge registration of the forces acting on the trunnion *in vitro* and *in vivo*, and finally—a continuous, long-term registration of a base material, the first presentation of which is published in this report.

DESIGN

Femoral component

The *prosthetic stem* is slightly curved in varus. In the transverse plane it has a rectangular form, the medial border of which is slightly curved. The length of the stem is either 130, 160 or 260 mm. The proximal end of the prosthesis carries a trunnion, the axis of which forms an angle of 115° with the long axis of the stem (Figure 1 A).

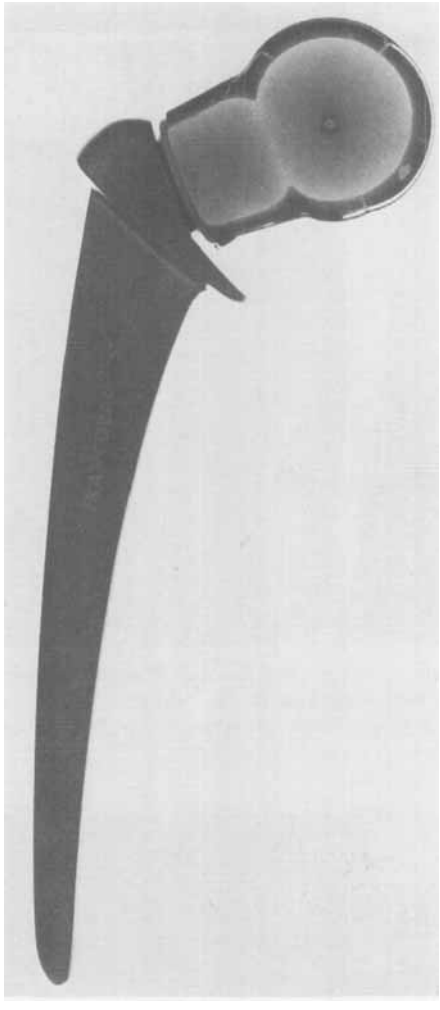

Figure 1 D. Trunnion bearing prosthesis assembled and ready for insertion into the femoral shaft.

The *prosthetic head* is designed according to a bushing principle. Thus, a cylindrical sleeve is slipped on to the trunnion. The sleeve is made of polyacetal (Delrin). On to this sleeve a casing is passed in the shape of a sphere with a neck of varying length and this completes the prosthetic head. The casing is either of stainless steel or vitallium and the neck can vary in length from 5 to 15 mm (Figure 1 B). The diameter of the head is 37 mm.

Acetabular component

The cup is made of polyacetal (Delrin) and has two external sizes: 47 and 51 mm, respectively.

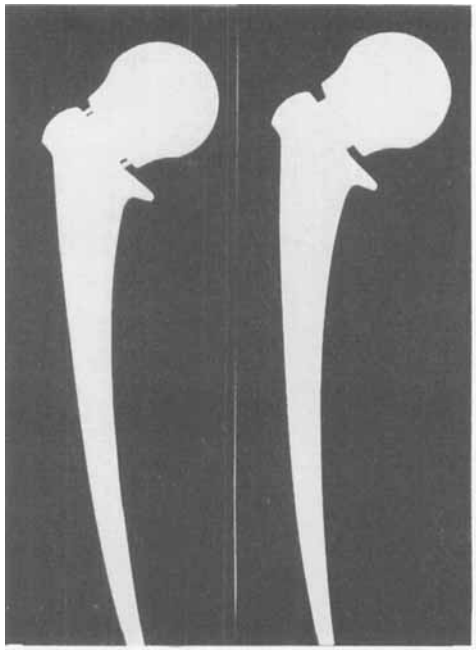

Figure 2. Trunnion bearing prosthesis equipped with metal markers in the cylindrical sleeve (left) for demonstration of rotation around trunnion (right).

Figure 3 A. Cineradiography of trunnion bearing prosthesis. Metal markers in cylindrical sleeve on opposite sides of trunnion.

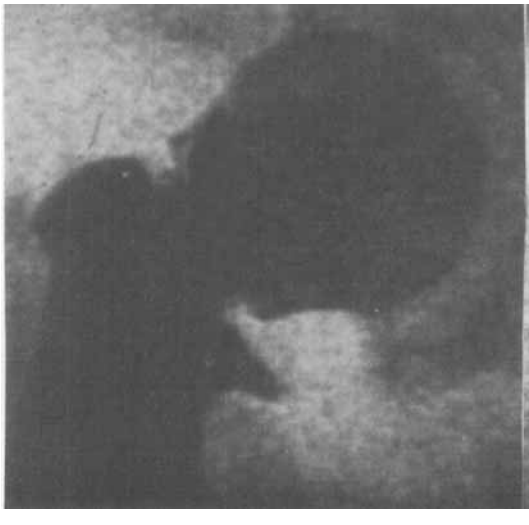

Figure 3 B. Same as Figure 3 A but after loaded flexion and extension, the patient walking with normal gait in front of the image intensifier. The markers in the cylindrical sleeve are beginning to disappear.

Figure 3 C. Same as Figure 3 A and 3 B but the patient has now been walking for 4 minutes and the markers in the cylindrical sleeve have disappeared indicating that a rotatory movement of the sleeve has occurred. This does not *necessarily indicate that the metal casing (the head) remains stationary in the acetabular cup.*

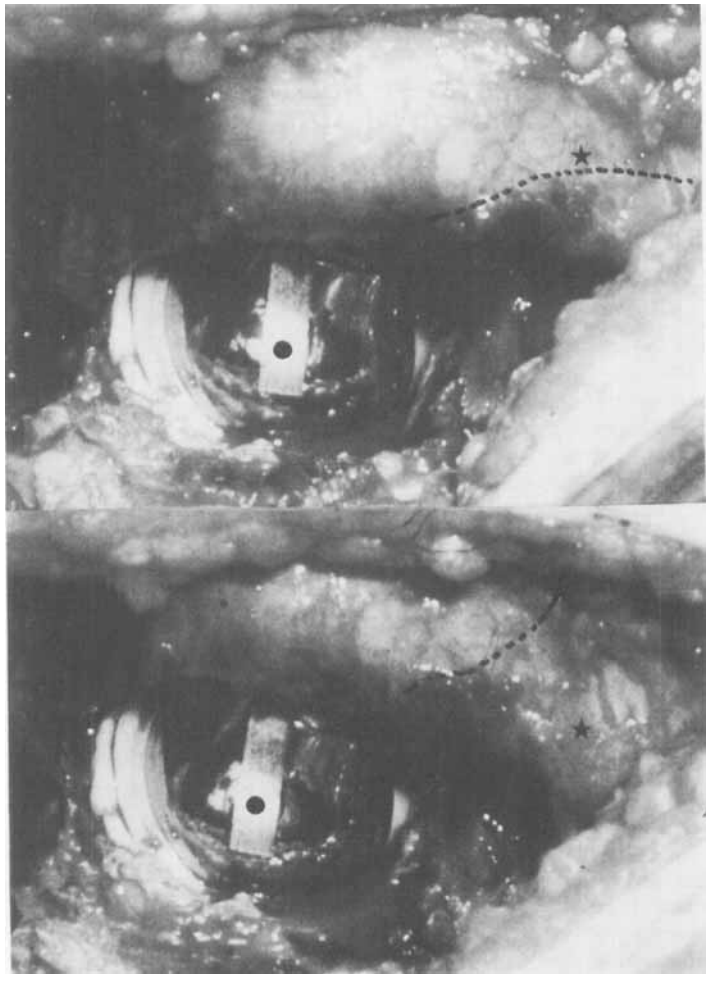

Figure 4. Right hip after total hip replacement with trunnion bearing prosthesis seen from a posterior approach. Top: the hip is extended. The outline of the trochanter major is indicated by a dotted line. The asterisk indicates the quadratus femoris muscle. The point indicates a steri-strip marker for identifying the position of the femoral head during loaded flexion extension. Bottom: flexion of the same hip as above to 80° under load. The steri-strip marker indicates no movement of the femoral head.

The internal diameter for both is 37 mm (Figure 1 C).

When assembled the prosthetic system appears as in Figure 1 D.

Delrin

Delrin is produced by the polymerization of formaldehyde. It is a polyacetal homopolymer and chemically known as polyoxymethylene or polyformaldehyde. It resists organic solvents, weak acids, bases and inorganic salts, e.g. 10 per cent solution of sodium chloride.

Delrin resists elevated temperatures and it has been autoclaved one hundred 15-minute cycles at 121°C steam with no significant loss of strength and due to this it can be used clinically.

In human skin patch tests no adverse reactions have been recorded and Delrin is not therefore regarded as a dermatitis hazard.

Delrin has higher tensile strength, higher yield strength, greater hardness and higher resistance than ultrahigh molecular weight polyethylene. The hardness of Delrin is equal to that of polymethylmethacrylate. The biocompatibility of Delrin is tolerable (Dumbleton 1977 personal communication).

Rationale for trunnion bearing prosthesis

In osteoarthrosis of the hip joint and in avascular necrosis of the femoral head replacement by the Austin-Moore prosthesis can be performed (Sarmiento 1973, Andersson & Möller Nielsen 1972). Migration of the prosthesis may occur with penetration through the acetabulum into the pelvis (Perkins 1961). This is caused by the friction which is generated by repeated movements between the metal head and the bone structures. In total hip replacement there is also friction, causing wear of the acetabular cup, which may jeopardize the results as the prosthesis may loosen (Charnley & Cupic 1973).

The object of the trunnion bearing prosthesis is to diminish the friction between the metal femoral head and the plastic acetabular cup. This is achieved by decreasing the movement between these components during loaded flexion and extension as occurs in, for example, walking. The bushing principle implies that the movements occur in the trunnion bearing system with the plastic sleeve rotating around the trunnion leaving the head stationary in the acetabular cup. There will thus be less wear and tear between the head and the acetabuum and the risk of wear in the acetabular cup is reduced to a minimum.

The background for this assumption is the biomechanics which develop in the Pauwels Type III fracture (Pauwels 1976) in which the fracture line is between 70 and 90°, i.e. almost a vertical fracture line. A stable internal fixation is counteracted by the shear forces which cause locking of the femoral head while the femoral shaft is free to move. With the axis of the trunnion bearing prosthesis designed at 115° the biomechanics simulates those of the Pauwels Type III fracture and thus the prosthetic femoral head should remain stationary in the acetabular cup on loaded flexion and extension.

Indications to support the assumption of movements of the cylindrical sleeve in relation to the trunnion

Investigation by cineradiography. Difficulties arise in demonstrating the movements actually taking place between the trunnion and the cylindrical sleeve whilst the metal casing (the head) remains stationary in the acetabular cup.

In an attempt to analyse the movements between the individual prosthetic components metal markers were inserted into the cylindrical sleeve at the edge bordering on the femoral stem. The neck of the metal casing (the head) was shortened so that the markers could be demonstrated at radiography (Figure 2). This specially prepared prosthesis was operated into a patient. One year following surgery a cineradiographic registration of the movements of the prosthetic system was made during loaded flexion and extension as in walking. It could then be demonstrated that the metal markers rotated around the trunnion. This was interpreted as a movement of the cylindrical sleeve around the trunnion but conclusive evidence could not be obtained by this examination that the metal head

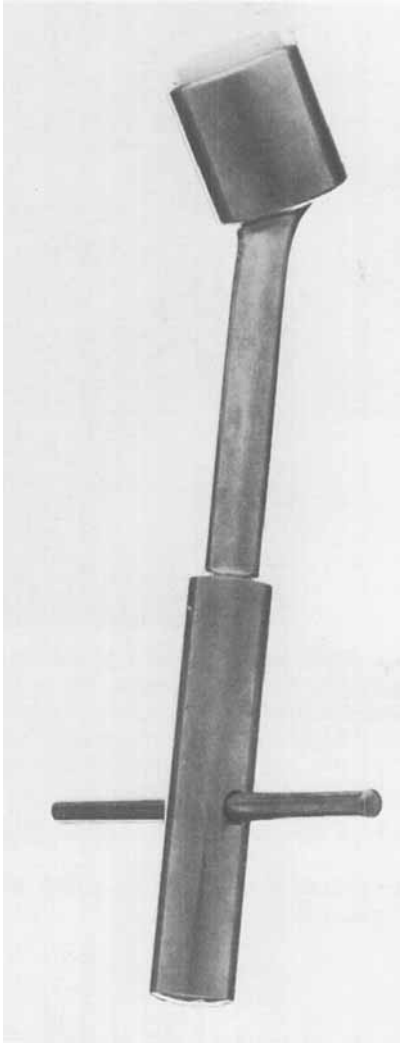

Figure 5. Guide for insertion of femoral stem in trunnion bearing prosthesis. Bar to be held parallel with the lower leg which is at 90° to the floor. Correct positioning of the femoral component can be expected.

remained stationary in the acetabular cup (Figure 3 A, B and C). The patient into whom this specially prepared prosthesis had been fitted has done very well: he has suffered no pain and has had no loss of function.

Observations at operation. To obtain further information as to whether the metal head remains stationary in the cup on loaded flexion and extension, tests of the prosthesis were carried out at operation. Once the prosthesis was inserted, the hip joint was flexed and extended and it then became evident that on *unloaded* flexion and extension there was movement of the metal head in the acetabular cup. On *loaded* flexion and extension the head remained in the same position with the movement taking place between the trunnion and the cylindrical sleeve (Figure 4 A and B).

Load distribution

The diameter of the head is chosen so as to cause a satisfactory balance between friction and loading per unit area of the prosthetic head which will diminish the effects of torque (Christiansen 1977). An increase in this may cause a loosening of the prosthesis. With the transfer of movements from the head and acetabulum to the trunnion and surrounding cylinder there is a redistribution of the load. This is believed to become linear instead of point limited as is the case in the conventional sphere prosthesis. This is supposed to lead to a longer life span for the trunnion bearing, the cylinder, the metal casing and the acetabular cup.

We are testing the above theory in practice. The results, however, are as yet not finalized for presentation.

CLINICAL STUDY

Material

In this particular study the trunnion bearing prosthesis has been used since 1975. (However, other prostheses, such as Brunswick, Charnley and McKee-Arden, have also been used.) In all, 78 patients have been operated on. However, as a minimum time for follow-up was set at 6 months, 22 patients (22 hips) who did not fulfil this time requirement were not included in this study. Therefore 56 patients (61 hips) remained for the follow-up (Table 1).

Sex and age are presented in Tables 2 and 3. The age distribution corresponds to that which is commonly found in similar series reported in the literature, i.e. a majority between 60 and 80 years of age. There were 49 hips with osteoarthrosis, ten hips with rheumatoid arthritis and two hips with ankylosing spondylitis.

Table 1. Number of patients/hips and year of operation for trunnion bearing total hip replacement

61 hips in 56 patients Year of operation	*n*
1975	9/9
1976	20/23
1977	27/29

Table 2. Sex distribution of patients treated with trunnion bearing total hip replacement

	Women	Men
Hips	38	23
Patients	35	21

Table 3. Age at operation of patients treated with trunnion bearing total hip replacement (61 hips)

Age at operation	No. of hips	Women	Men
<60	15	9	6
60–69	28	20	8
70–79	17	8	9
>80	1	1	

Operative technique

All patients were operated on by one of the authors (I.G.) and a posterior approach was used. The recommendations of Christiansen were followed (Christiansen 1977, personal communication). One detail worth mentioning is the guide (Figure 5) for the insertion of the femoral prosthesis. The guide is equipped with a bar and passed on to the trunnion. The bar is placed parallel to the lower leg which is at 90° to the floor. In this way the femoral prosthesis is placed in the correct anteversion position.

Follow-up. A follow-up was carried out in February 1978 by one of the team not acquainted with the patients pre- or postoperatively (C.R.). Of the 56 patients one had died, thus leaving 60 hips

in 55 patients to be followed up. Two patients refused to participate but enough information could be obtained by telephone interview to make evaluation of the results possible. Thus, 58 hips could be evaluated by personal examination. The follow-up time varied from 6 months to more than 3 years; for a majority of the patients it was just over 2 years (Table 4).

Table 4. Length of follow-up in 55 patients (60 hips) treated with trunnion bearing total hip replacement

Follow-up time (years)	No. of hips
<1	15
1–2	32
2–3	11
>3	2

RESULTS

Pain

The results as rated by the numerical system of Merle d'Aubigné & Postel (1954) are presented in Tables 5 and 6. For the total material there was complete freedom of pain in 50 per cent and a considerable decrease in pain in 20 per cent, thus giving satisfactory results as regards pain in 70 per cent. There were eight patients who suffered some pain only after a certain amount of activity and who became pain-free after rest. These patients belonged to the osteoarthrosis group and will be discussed below. There were two patients who still had severe spontaneous pain, one of whom belonged to the osteoarthrosis group and the other to the rheumatoid arthritis group. The reason for the persistent pain could not be explained clinically. On objective examination the range of motion was good and radiography did not disclose any abnormalities.

As for the osteoarthrosis group, complete freedom of pain occurred in 53 per cent and a considerable decrease in 22 per cent, thus giving a satisfactory result in 75 per cent. In this group there were eight patients who suffered pain only after some activity with disappearance of pain at rest. These patients were rated 4 in the rating system as it was difficult to give them a place which corresponded to their condition. They did not complain as much of pain as of a discomfort which they had difficulty in describing. Despite this they were all pleased with the result of the operation. They all had a positive Trendelenburg's sign and also used a cane when walking for longer distances. No cane was used on walking shorter distances and the reason for using a cane was simply a matter of security.

As for the rheumatoid arthritis group this was very small but still the results were quite rewarding as no pain was experienced in 75 per cent.

The average grade for pain in the total group was 5.1 points; in the OA group 5.2 points and in the RA group 4.7 points.

Walking

Of the total group 10 per cent walked without a cane. Fifty-six per cent had limited walking capacity without a cane and 25 per cent could walk long distances with one cane. Looking at the individual groups 8 per cent of the OA group walked normally and this applied to 1.6 per cent of the RA group. Quite a number of patients (total 34) in both groups could walk without a cane but had a limp. The general impression was a decided satisfaction with the improvement achieved by the operation (Table 6).

Range of motion

The total motion is registered in Table 7 and the movement is expressed as the sum of degrees of movement in all three standard directions. On the whole the movement reached a total of 165°.

Table 5. Registration of pain at follow-up in 60 hips operated with trunnion bearing total hip replacement

Pain	Points	Number of hips		
		total	osteo-arthrosis	rheumatoid arthritis
Severe Spontaneous	1	2	1	1
Severe on attempting to walk, prevents all activity	2	–	–	–
Pain tolerable permitting limited activity	3	5	2	3
Pain only after some activity, disappears quickly with rest	4	8	8	–
Slight or intermittent pain on starting to walk, diminishing with normal activity	5	12	11	1
No pain	6	33	26	7
Total		60	48	12

Trendelenburg's sign

Trendelenburg's sign was positive in 49 hips which may explain the high number of limps registered. It should be mentioned, however, that very little pain accompanied the limp. The reason for limping is difficult to clarify but speculations have been made regarding preoperative muscle weakness due to pain and limited function in the diseased joint, and it has also been suggested that the posterior approach may have some influence.

Complications

The complications registered were infections (superficial and deep), thromboembolism, dislocations, ectopic bone formation and loosening. The infections are presented in Table 8; there were six superficial infections and one deep. Prophylactic antibiotics were administered during the operation and for 7 days following the operation (day of operation: 3 g cloxacillin in 500 ml invertos during 6 hours and a repeated dose during the following 6 hours; 0.5 g dicloxacillin for 7 days postoperatively). As soon as a discharge was noted in the wound, cultures were taken. The six hips with superficial infection healed within the period of administration of prophylactic antibiotics and no supplementary treatment was given.

The one instance of deep infection probably occurred as a result of metastatic infection; 1 year previously the opposite hip had been operated on for a pertrochanteric fracture and at this time an infection developed. The infection in the hip joint replaced with a trunnion bearing prosthesis appeared on the third day after operation. The antibiotic treatment was therefore pro-

Table 6. Walking ability at follow-up of 55 patients (60 hips) treated with trunnion bearing total hip replacement

Walking	Points	Number of hips		
		total	osteo-arthrosis	rheumatoid arthritis
Bedridden or can walk a few yards. Two sticks or crutches	1	–	–	–
Time and distance very limited with or without sticks	2	3	1	2
Limited with one stick (less than 1 hour) Difficult without stick Able to stand long periods	3	2	2	–
Long distances with one stick Limited without a stick	4	15	13	2
No stick but a limp	5	34	28	6
Normal	6	6	4	2
Total		60	48	12

Table 7. Total range of movement in 58 hips treated with trunnion bearing total hip replacement

Total range of movement	Points	Number of hips
0– 30	1	–
30– 60	2	–
60–100	3	1
100–160	4	25
160–210	5	27
210	6	5
Mean value points	5.1	

longed. There was complete healing and 6 months after the operation the patient was completely free of pain (Grade 6) and had no radiologic signs of loosening.

In Table 9 the remaining complications are recorded. The thromboembolism did not lead to any serious complications. The early dislocation occurred on the 14th day after operation, the reason being unknown. A closed reduction could be performed without difficulty and no further complications occurred. The late dislocation occurred some months after the operation and this patient has dislocated no less than three times.

Ectopic bone formation occurred in 11 hips but without clinical significance as neither pain, walking ability or range of motion were influenced by this development.

Loosening occurred in two femoral stems and these patients are candidates for re-operation. At the time of follow-up the loosening did not appear to be infectious in origin.

There were no further complications such as penetration of the femur or acetabulum, no nerve injuries or allergic reactions.

Thus, there were serious complications in four cases, i.e. 6.5 per cent, and complications of a minor significance occurred in 12 hips, i.e. 20 per cent.

Table 8. Infections in 61 hips treated with trunnion bearing total hip replacement

Type	Number	Bacteria	Remarks
Superficial	6	Staph. epidermidis Enterobacts Proteus Pseudomonas	Healed within period of administration of prophylactic antibiotics No supplementary treatment No influence on result
Deep	1	Staph. aureus Pseudomonas	Complete healing. After 6 months rated as Grade 6.

Table 9. Further complications in 61 hips treated with trunnion bearing total hip replacement

Type	Number
Thromboembolism	5
Dislocations–early	1
late	1
Ectopic bone formation	11
Loosening–Femoral prosthesis	2

DISCUSSION

The bushing principle as employed in the trunnion bearing prosthesis is an attempt to diminish friction between the articulating surfaces. Friction is assumed to have a serious effect on the properties of the articulating surfaces, on the bonding of the prosthesis to cement and in turn to bone. The small-sized femoral head (22 mm) of the Charnley prosthesis was especially designed in this way to diminish friction. Even so, Charnley claimed that wear of the acetabular cup must be accepted and calculated that 0.1–0.3 mm surface wear per year could be expected in the acetabular cup. Furthermore, late results as reported by Charnley (1978) have confirmed that a certain amount of wear in the cup cannot be avoided but clinically this does not appear to have any serious consequences. The loosenings reported were due to a greater extent to faulty operative technique: the cup was placed too deeply into cancellous bone and too high instead of more medially.

In a series of laboratory tests on cadaver hips Andersson et al. (1972) were able to show that the effect of friction on the attachment of the cup to the bone did not exceed that of the loading necessary to break this attachment. Their conclusion was that mechanical factors could not be held responsible for loosening but rather it could be attributed to septic, thermal or inflammatory factors.

Contrary to this Simon et al. (1975) demonstrated that friction in total hip replacement was forty times greater than that of a normal hip. On further analysis they found that the friction which is generated on initiating a movement, so called stiction-friction, far exceeds that of the dynamic friction which occurs during, for example, walking. They therefore concluded that loosening was more an effect of the initiation of movement than of continuous movement.

In view of this the bushing principle appears as an attractive alternative to the conventional ball and socket joint principles. With the femoral head stationary in the acetabular cup on loaded flexion and extension, friction should be reduced to a minimum. In the present investigation some indications have been presented to support the concept of the metal head remaining stationary with the movement taking place between the trunnion and the cylindrical sleeve. It remains, however, to be proved that this actually occurs in daily walking.

It cannot be excluded that mechanical factors such as friction can cause loosening. In 1975 Dandy & Theodorou reported 1,042 total hip replacements with the McKee-Farrar prosthesis. After 2 years, loosening occurred in 113 hips (9.2 per cent). In 83 of these mechanical factors were the obvious cause.

In other reports loosening has occurred between 2 to 3 years postoperatively in 9–11 per cent but in some of these infection cannot be excluded (Amstutz 1970, Pattersson & Selby-Brown 1972, Wilson & Scales 1970, Lazansky 1973, Nolan et al. 1975).

In this investigation the mean follow-up time has been 2.3 years and two femoral stem loosenings have been recorded (3.3 per cent). So far there have been no signs of cup loosenings. A cautious assumption may be made that the bushing principle causes less friction and thus lessens the risk of loosening.

REFERENCES

Amstutz, H. C. (1970) Complications of total hip replacement. *Clin. Orthop.* **72,** 123–137.

Andersson, G. B. J., Freeman, M. A. R. & Swanson, S. A. V. (1972) Loosening of the cemented acetabular cup in total hip replacement. *J. Bone Jt Surg.* **54**-B, 590–599.

Andersson, G. B. J. & Möller Nielsen, J. (1972) Moore's arthroplasty results after 8 years. *Acta orthop. scand.* **43,** 397–410.

Charnley, J. (1970) *Acrylic cement in orthopaedic surgery.* E & S Livingstone, Edinburgh and London.

Charnley, J. & Cupic, Z. (1973) The nine and ten year results of the low-friction arthroplasty of the hip. *Clin. Orthop.* **95,** 9–22.

Charnley, J. (1975) Fracture of a femoral prosthesis in total hip replacement. *Clin. Orthop.* **111,** 105–120.

Charnley, J. & Weber, S. (1975) A radiological study of fractures of acrylic cement in relation to the stem of a femoral head prosthesis. *J. Bone Jt Surg.* **57**-B, 297–301.

Charnley, J. (1978) Late results of total hip replacement—12 to 15 years. 8th Course on Operative Treatment of Osteoarthritis of the Hip Joint. Bern, April 3–6, A-O Documentation.

Christiansen, C. H. T. (1969) A new hip prosthesis with trunnion bearing. *Acta chir. scand.* **135,** 43–46.

d'Aubigné, R. M. & Postal, M. (1954) Functional results of hip arthroplasty with acrylic prosthesis. *J. Bone Jt Surg.* **36**-A, 451–473.

Dandy, D. J. & Theodorou, B. C. (1975) The management of local complications of total hip replacement by the McKee-Farrar technique. *J. Bone Jt Surg.* **57**-B, 30–35.

Eftekhar, N. S. & Stinchfield, E. (1973) Total replacement of the hip joint by low friction arthroplasty. *Orthop. Clin. N. Amer.* **4,** 483–501.

Lancet (1976) Editorial, 31.1, pp. 234–235.

Lazansky, M. G. (1973) Complications revisited. The debit side of total hip replacement. *Clin. Orthop.* **95,** 96–103.

Nolan, D. R., Fitzgerald, R., Beckenbaugh, R. & Coventry, M. (1975) Complications of total hip arthroplasty. *Orthop. Clin. N. Amer.* **4,** 483–501.

Patterson, F. P. & Selby-Brown, C. (1972) The McKee-Farrar total hip replacement. *J. Bone Jt Surg.* **54**-A, 257–273.

Pauwels, F. (1976) *Biomechanics of the normal and diseased hip.* Berlin, Springer-Verlag.

Perkins, G. (1961) *Orthopaedics,* pp. 469–482. University of London, The Athlone Press.

Sarmiento, A. (1973) Moore's arthroplasty in osteoarthritis. Instructional Courses, American Academy of Orthopaedic Surgeons, Washington.

Simon, S., Paul, J., Roos, R. & Radin, E. (1975) Stiction-friction of total hip prosthesis and its relationship to loosening. *J. Bone Jt Surg.* **57**-A, 226–230.

Wilson, J. A. & Scales, J. T. (1970) Loosening of the total hip prosthesis with cement fixation. *Clin. Orthop.* **72,** 145–160.

Correspondence to: Ian F. Goldie, Department of Orthopaedic Surgery II, Sahlgren Hospital, University of Göteborg, Göteborg, Sweden.